ELSEVIER Microelectronic Engineering 29 (1995) 101-104

MICROELECTRONIC ENGINEERING

Thin nickel films as absorbers in pyroelectric sensor arrays

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During the evaporation of nickel on quartz, the square resistance and the IR–transmittance have been investigated simultaneously. A modified Namba model is introduced to explain the measured thickness dependence of resistivity. Inferences on the film growth and the percolation threshold are obtained, which are both important with respect to the absorber quality and fabrication. Thin nickel films of various thicknesses have been deposited on pyroelectric polyvinylidene fluoride (PVDF) films. The transmittance of these two–layer–systems has been measured in the infrared spectral range $2\,\mu$m – $50\,\mu$m and is compared with theoretical simulations. The absorber characteristic can be varied by an appropriate selection of the thickness of the nickel film. This allows the realization of broadband absorber and of selective absorbers as well. PVDF films coated with optimized nickel absorbers have been used in integrated pyroelectric sensors.

1. INTRODUCTION

The absorption of incident radiation is the first of several physical processes involved in the generation of an electrical output signal by a pyroelectric sensor. In order to achieve a high sensitivity from the sensor, the absorption must be performed as efficiently as possible. In the next step, the absorbed energy flows to the pyroelectric element. To achieve a fast and efficient energy transfer, a high heat conductivity but a low heat capacity absorber is required. Last but not least it should be possible to manufacture the absorber by a non–critical process with a high reproducability. This is in particular essential for the production of sensor arrays, where equal sensitivities of all pixels are required. These requirements can be fulfilled by the use of thin metal films.

In recent theoretical work [1] it has been shown that the optical properties of a homogeneous thin metal film in the infrared are well described by its square resistance. To allow the reproducible manufacturing of a film with a distinct square resistance $R_\square \approx 200\ \Omega$ by evaporation, the metal film must grow in the form of a homogeneous layer. In particular, the percolation threshold of the material used has to be low compared to the required film thickness.

Financial support by the European Community through the Brite-Euram programme is gratefully acknowledged.

To investigate the relation between the square resistance and the optical transmittance of thin nickel films, both quantities have been measured simultaneously during evaporation. The comparison with theoretical models allows inferences on the film growth and on the percolation threshold.

2. THEORY

2.1. Optical and electrical properties

For a homogeneous thin metal film of thickness d embedded between two dielectric materials with refractive indices $\tilde{n}_i$ and $\tilde{n}_t$, the amplitude reflection and transmission coefficients for the electric field strength are given by [1]:

$$r = \frac{\tilde{n}_i - \tilde{n}_t - y}{\tilde{n}_i + \tilde{n}_t + y}, \qquad t = \frac{2\tilde{n}_i}{\tilde{n}_i + \tilde{n}_t + y}. \qquad (1)$$

In this case the light is incident on the metal film from the medium with refractive index $\tilde{n}_i$. The optical properties are completely described by $y = d/\epsilon_0 c\rho$, which is the dimensionless quotient of the vacuum impedance $1/\epsilon_0 c$ and the square resistance $R_\square = \rho/d$ of the metal film. ϵ_0 denotes the permittivity of vacuum, c the velocity of light, and ρ the resistivity of the metal. This simple relation is valid, if the thickness of the metal film is small compared with the wavelength and the penetration depth of the incident radiation.

0167-9317/95/$09.50
SSDI 0167-9317(95)00124-7